1-1-2020

The Impact Of Medicaid Expansion On Childhood Vaccination Rates, 2010-2018

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A Thesis

Presented to

The Faculty of the Department of Epidemiology of Microbial Diseases

Yale School of Public Health

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In partial fulfillment of the requirements for the degree of

Master of Public Health

by

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May 2020

Abstract

Background

The relationship between coverage expansions and vaccination coverage is not well characterized, through previous work as linked coverage expansions with insurance rates and insurance rates with vaccination completion. We examined whether Medicaid expansions implemented by the end of 2015 in 29 states and D.C. were associated with changes in MMR vaccination and 7-series vaccination completion among low income children from 2010-2018.

Methods

Changes in mean vaccination coverage were compared between the four years before expansion (2010-2013) and the four years post expansion (2015-2018), using data from the 2010-2018 National Immunization Child Survey. The final study sample (N=36,591) included children with provider-confirmed records from families with incomes up to 138% of the federal poverty level with whom information on all relevant covariates was available. Outcomes were whether a child had completed the recommended 7-series vaccination sequence and whether a child had received 1 or more doses of MMR vaccine.

Results

Medicaid expansion was not significantly associated with mean vaccination coverage for either MMR (difference-in-differences estimate, 0.82 percentage points, p=0.48) or 7-series vaccination completion (difference-in-differences estimate, -0.84 percentage points, p=0.65). Calendar time, age group of child, number of children in household, census region, and educational status of mother were significantly associated with changes in mean vaccination rate for both outcome measures.

Conclusions

This provides useful insight into the potential benefits of current public vaccination programs, but suggests their insufficiency in closing the vaccination gap between low income and high income children. Broad coverage expansions may not reduce vaccination disparities between low income and high-income children, and alternative solutions should be explored.

Table of Contents

List of Figures

Acknowledgements

I would like to thank my thesis advisers, Saad Omer and Linda Niccolai, for help in conceptualizing this study and for continuous feedback throughout the process.

I would also like to thank Bob Bednarczyk, Jacob Wallace, and Amyn Malik for helping me work through the logistics of building the model. Without their help in talking through the details of the methods section, I would not have been able to complete this project.

To my faculty adviser, Nathan Grubaugh, for his patience and honest feedback for the past two years, and his constant efforts to help me succeed, despite our vastly different research interests.

Lastly, I would like to thank my friends and family who have listened to me talk about this project and the process continuously over that past year—without their patience and encouragement, this process would have been much more difficult and stressful.

It is my hope to continue to approach epidemiology and public health through an equity lens to promote those who are most vulnerable among our communities. Now more than ever, it is critical to think of the downstream impacts of key policy decisions—and how they differentially value groups of people.

Introduction

Maintenance of vaccination coverage is essential for the population's health, resulting in dramatic reductions in mortality and elimination and eradication of disease (Orenstein and Ahmed, 2017). In 2019, at least 1,260 cases of measles were identified between January and November, the largest outbreak since 1992 (CDC). While vaccination coverage remains high among children in the United States, (91.9% in 2013), outbreaks of highly infectious diseases like measles remain concerning due to clustering of unvaccinated children (Phadke et al, 2016). A 2005 study found that only 18% of children received recommended vaccinations on time or sufficiently early (Luman, 2005). Low income children are particularly vulnerable to lower vaccination coverage, perhaps partially due to insurance status, though this disparity is declining (Smith et al, 2009, Hill et al, 2018).. Variation in vaccination coverage by health insurance status has been shown to play a role in creating pockets of susceptibility, with substantially lower coverage (14.7-30.3%) among uninsured children, and slightly lower coverage among Medicaid-insured children (2.5-15.0%) when compared to children on private insurance(Hill et al, 2018). While much of conversation around recent outbreaks and coverage has revolved around vaccine hesitancy, a lesser discussed determinant of vaccination coverage that demands further study is insurance status.

Health insurance is associated broadly with better health and utilization of preventive services, including vaccinations (Stoeker et al, 2017). For children, uninsured or underinsured children are more likely to be referred to a public clinic for vaccination, decreasing their likelihood of vaccination completion (Freed et al, 1999). Severe delays in vaccine completion among children have additionally been associated with race/ethnicity, use of public vaccination providers or multiple vaccination providers, living in a single parent household, and household with 2 or more children (Luman, 2005). Programs like the Vaccines for Children Program and Medicaid aim to lessen this disparity in vaccination coverage among publicly, privately, and uninsured children by covering vaccination for uninsured children in their provider's office, decreasing use of public clinics (Sanofi et al, 2004). Type of insurance status is also critical to vaccination coverage. One study found that children on Medicaid had less vaccine uptake than those on private insurance, but uptake was still higher than those uninsured (Bhatti 2018 Public insurance may additionally facilitate continuity of care and increase completion rates (Blewett et al, 2008). It is plausible that public insurance programs and coverage expansions may positively impact vaccination coverage.

Though a few studies have found an association between insurance coverage and vaccination rates, there is limited research on the impact of coverage expansions on vaccination rates. In 2010, the Affordable Care Act (ACA) expanded Medicaid eligibility to all adults up to 138% of the poverty level, but this expansion was ruled optional in 2012's *NFIB v. Sebelius,* leading to differential expansion of the program (Miller and Wherry, 2017)*.* Full implementation of the ACA occurred in 2014-2015, dramatically increasing insurance coverage among low-income adults in expansion states (Miller and Wherry, 2017, KFF). Medicaid expansion has been shown to improve access to preventive health services among adults, including flu vaccination (Simon and Cawley, 2017). Additionally, low income residents have been found to be significantly worse off in terms of health insurance coverage, health outcomes, and have less care utilization in states that did not expand, all of which can potentially adversely affect children's vaccination rates (Han et al, 2015, Choi et al, 2018).

Studies have additionally found a link between parent eligibility for Medicaid and the subsequent enrollment of children into health insurance. Though vaccinations and health care for children are provided through the Vaccines for Children program and CHIP, which both have proven efficacy, vulnerable groups still tend to under-enroll—spillover effects from coverage expansions are thus important to consider. Medicaid expansion helped align eligibility thresholds, facilitating enrollment of vulnerable populations and their children in health insurance (Whitney et al, 2014, MACPAC). Medicaid expansion may have facilitated uptake of Medicaid among already eligible children though additional investment in outreach and coordination among expansion states as well as joint parent-child eligibility for and coverage by Medicaid (Hudson and Moriya, 2017). Care expansions targeted at low income adults have resulted in increased Medicaid coverage among previously eligible parents, and have been associated with increased utilization pediatric preventive care for their children, a so-called “spillover effect” (Venkataramani et al, 2017, Kenney, 2019).

It is plausible to consider that Medicaid expansion may similarly have also had an impact on childhood vaccination rates. There is evidence that differing provisions for coverage among public health programs as well as insurance status can impact a family’s ability to obtain vaccines, both of which are affected by Medicaid expansion’s impact on enrollment in public insurance programs (Hudson and Moriya, 2017). To date, we are not aware of any such study that looks at the impact of Medicaid expansion on childhood vaccination rates. This study aims to clarify and quantify the impact of Medicaid expansion on childhood vaccination coverage in the United States, and to look further into policy determinants of immunization rates. Our study aims to provide a comprehensive picture of the effects of large scale policy change on childhood immunization with the goal of reducing persistent inequities in access and utilization of preventive services among low income individuals.

Methods

Study Design

Using a quasi-experimental difference in differences design to changes in mean vaccination coverage were compared among low-income children in expansion versus non-expansion states before and after Medicaid expansion was implemented. Following criteria outlined in previous studies (Miller and Wherry, Yue et al), we defined expansion as states implementing Medicaid expansion by the end of 2015. States that already provided Medicaid or similar coverage for low income individuals were excluded from this analysis (N=12,234). 2014 was not analyzed in the primary analysis due to its status as a transitional year in which full enrollment would not have been observed, potentially diluting an effect size (Miller and Wherry, 2017, Sommers 2014). The post-expansion period was defined as 2015-2018, by which all the “expansion” states would have implemented the expansion. The study period includes four years prior to expansion (2010-2013) and four years after expansion (2015-2018). More details on the study sample are available in the appendix.

Data

Data from the 2010-2018 National Immunization Child Survey (NIS-Child) was used for the main analysis (CDC 2010-2018). The NIS Child dataset collects information on demographic and geographic factors, health insurance coverage, and vaccination coverage on a yearly basis using a random digit dialing method surveying noninstitutionalized parents and guardians in all 50 states, DC, and some territories. Parents and guardians of eligible children were asked for provider information and permission to contact them. Providers then confirmed information on the types of vaccinations, number of doses, and data about the health care facility, which was then aggregated and coded to indicate whether a child is up to date according to Advisory Committee on Immunization Practices (ACIP) guidelines. The final study sample (N=36,591) included children with provider-confirmed records from families with incomes up to 138% of the federal poverty level with whom information on all relevant covariates was available.

Outcome Measures

The primary outcome measures were 1 or more doses of MMR containing vaccination and up to date 7 series vaccination completion, 4:3:1:3:3:1:4 (4 or more doses of DTaP, 3 or more doses of Polio, 1 or more doses of MMR, Hib full series (3 doses, using the strict definition), 3 or more doses of HepB, 1 or more doses of Varicella, and 4 or more doses of PCV) as defined by CDC vaccination guidelines. Outcome measures were coded as binary variables that indicated whether either series completion or one or more dose of vaccination was received.

Statistical Analysis

Descriptive statistics for expansion and non-expansion states were calculated separately for the pre and post expansion periods.

Multivariate linear regression models were used to compare changes in outcomes over time in expansion versus non-expansion states, and for calculating difference-in-differences estimates. Regressions included interactions between a binary variable indicating whether the state had adopted Medicaid expansion by the end of 2015 and whether the time period was preexpansion (2010-2013) or post expansion (2015-2018). Covariates of this analysis were defined *a priori* based on similar studies and known factors associated with under-vaccination (Miller and Wherry, 2018, Yue et al, 2018, Luman 2005), including sex of child, age group of child, number of children in household, educational status of mother, marital status of mother, race/ethnicity of child, and census region. The estimate of the coefficient on the interaction gave the mean difference in expansion and non-expansion states during the post period, as compared with the period before expansion, adjusting for covariates. All analyses were conducted with SAS software, accounting for the sampling design of the NIS-Child data.

The validity of a differences-in-differences design is contingent on the following assumptions: the allocation of the intervention is unrelated to the outcome at baseline, that the composition of intervention and control groups are stable over time, and that in the absence of treatment, the difference between the treatment and control group is constant over time ("parallel trends"). The first two assumptions are satisfied through assessment of the composition of the group over time (Table 1). To assess the "parallel trend" assumption, vaccination coverage trends in non-expansion and expansion states were assessed visually. To examine the sensitivity of our analysis to alternative sample definitions, the model was run utilizing 2014 data and defining expansion states as those who expanded Medicaid by 2014, to individuals up to 100% of the federal poverty level***,*** and to all individuals in our sample regardless of income level. To test the sensitivity of the model to common secular trends across states, we controlled for a yearly trend.

Results

Descriptive analyses

Of the states included in the analysis, 20 implemented Medicaid expansion on January 1, 2014; 3 states implemented expansion by January 2015, and 2 states implemented expansion after January 2015—all of which were considered expansion for the primary analysis. Table 1 shows the demographic characteristics of respondents in the pre-expansion and post expansion period, based on expansion status of states. Households in the post period had a higher proportion of unmarried parents, and households in non-expansion states had a higher proportion of unmarried parents (64.68% vs. 60.70% in the post period, 60.21% vs. 56.28% in the pr period). Children living in expansion states were more likely to be Hispanic (46.31% vs. 36.12% in the pre period, and 43.9 vs. 34.40% in the post period) and to be female. (26.38% vs. 23.68% in the pre period and 36.46% vs. 35.95% in the post period). Children in non-expansion states were more likely to have unmarried parents (60.21% vs. 56.28% in the pre period and 64.68% vs. 60.70% in the post period).

Trends in Outcomes

Figures 1 and 2 show plots of mean vaccination coverage among low income children in expansion and non-expansion states, from 2010 to 2018. The mean vaccination coverage for both 7 series and MMR containing vaccinations trend similarly, but diverge in 2013. Both 7 series vaccination and MMR mean coverage seem to be higher among low income children in many non-expansion states. The temporal trends in outcomes were mainly parallel (with the exception of a slight difference in 2012), confirming the validity of the difference in differences model utilized.

Effects of Medicaid Expansion on MMR and 7-series vaccination coverage

Table 2 shows the adjusted difference-in-differences estimates of the impacts of Medicaid expansion on MMR vaccination coverage and 7 series vaccination completion among low income children from 2010-2018.. Among low income children, Medicaid expansion was not significantly associated with increases or decreases in mean vaccination coverage or either outcome measure.

Effects of time and demographic factors on MMR and 7-series vaccination coverage

In contrast, later time period was significantly associated with mean vaccination rates for both MMR (coefficient estimate, -1.92 percentage points, p=0.005) and 7-series completion (coefficient estimate, 4.37 percentage points, p<0.001) (Table S1). These contrasting findings indicate that vaccination completion may be going up independently over time, but MMR vaccination may be declining independently of Medicaid expansion. Census region, age group of child, number of children in household, educational status of mother, and Hispanic ethnicity were significantly associated with 7-series completion. Census region, age group of child, number of children in household, marital status of mother, race/ethnicity, and post-secondary educational status of mother were significantly associated with MMR vaccination (Table S1). Expansion was not significantly associated with changes in mean vaccination rates.

Sensitivity Analyses

Adjusting for a linear time trend found no meaningful changes in the results, nor did adjusting the expansion criteria and including 2014 in the analysis. When analyses were restricted to individuals of 100% of the FPL, the difference in difference estimator became less significant, as other covariates became more significantly associated with the outcome measures (notably, all covariates except sex of child and marital status of child were significantly associated).

Discussion

Evidence about the impact of Medicaid and CHIP expansions on specific health outcomes are mixed, specifically for chronic conditions and hospitalizations (Howell et al, KFF). Similar to other studies that did not find significant changes in flu vaccination among low income adults (Miller and Wherry 2017, Simon, Soni and Cawley 2017, Yue et al 2018), we did not find significant changes in vaccination uptake for either MMR or 7 series completion among low income children. Additionally, year specific estimates indicated a slightly higher mean vaccination coverage among non-expansion states, though non-significant. This may be due to differences in provisions of vaccination programs, behaviors, state policies, and CHIP provisions (KFF). Interestingly, mean MMR coverage was associated with significant declines in the later time period, while 7-series vaccination completion was associated with increases over time across both groups of states. The contrasting independent associations of calendar time with MMR coverage and vaccination completion suggest that while vaccination completion may be going up broadly over time, certain clusters may have faced declines in uptake in 2015-2018. This pattern of behavior may be consistent with the 2019 measles outbreak—while low income US children may be increasing completion of all recommended vaccinations over time, clusters of vaccine hesitant behavior may have led to this decrease in MMR coverage and led to outbreaks. While interesting, these findings are tangential to the main focus of this study, and may be viable topics for further research.

There are a few plausible reasons for the non-significant interaction term: firstly, the time period or outcomes studied may not have been sufficient to observe changes in vaccination behavior. More recent rising levels of uninsured children may also not have been captured in this data. Alternatively, this finding provides evidence that programs like the Vaccines for Children Program or CHIP may be sufficient to fill the vaccination coverage gap.

It is possible that the time period under study may not have been long enough to observe changes in vaccination behavior. There may be a lag time between newly eligible persons to learn about Medicaid and enroll, and coverage expansions often take several years to reach full enrollment ((Miller and Wherry, 2017, Sommers and Blendon, 2016). Additionally, as most vaccinations are given between 19 and 35 months, effects on vaccination coverage for their children may not be seen until years later. As a result, though this study included a period of four years post-expansion, this may not have been sufficient to observe uptake in vaccination related to Medicaid expansion.

Additionally, in many non-expansion states, children are losing their insurance coverage from Medicaid and CHIP, resulting in a rise of 400,000 uninsured children from 2016-2018 (Goodnough and Sanger-Katz, 2019). Though some attribute this to rising employment levels, there is evidence that this coverage drop is at least partially due to the imposition of more frequent eligibility checking in states like Texas and Tennessee and deportation concerns for states with high proportions of immigrants, like Florida (Goodnough and Sanger-Katz, 2019). Between 2016-2018, uninsured rates of children have raised by as much as 1.5% in many non-expansion states, often within areas with the highest unemployment rate (Goodnough and Sanger-Katz, 2019). This declining coverage, while concerning, is too recent for impacts in terms of health outcomes to have been observed within our study period. While our current results indicate a non-significant impact of Medicaid expansion, this rising coverage gap in non-expansion states could potentially have effects in the future.

This null finding may suggest that the Vaccines for Children and the Child's Health Insurance Program (CHIP) are ensuring sufficient insurance coverage, and by extension, outcomes, among low income children. This is supported by the fact that time alone was significantly associated with increase in mean 7-series completion, suggesting that vaccination completion is going up broadly over time, perhaps independently of coverage expansions, though MMR coverage appears to be significantly declining over time. The Vaccines for Children program has been shown to decrease likelihood of physician referral to a public vaccine clinic (due to service provision in office), and resulted in savings in direct and indirect costs by averting illness, hospitalizations, and deaths (Zimmerman et al, Whitney). Similarly, data support that CHIP has increased health insurance coverage among children and improved access to care and utilization of services among low in come children (KFF). However, gaps in access to care persist, and may feed into disparities in vaccination coverage between low-income and higher income children (KFF). Though these gaps in coverage are decreasing, suggesting that the programs are working, persistent disparities may indicate that simply expanding coverage may not be sufficient to eliminate inequities in vaccination coverage. Our findings similarly suggest that among low income children, providing insurance coverage expansions did not improve vaccination coverage, and Medicaid expansion is therefore unlikely to be beneficial in increasing vaccination uptake this at-risk group.. It is possible that insurance coverage alone is not enough to increase vaccination coverage. For the purposes of this analysis, states are classified as non-expansion if they did not expand by the end of 2015, utilizing the traditional route of Medicaid expansion. Some states classified as non-expansion in this study have instead expanded through 1115 waivers, which allow for more state flexibility and autonomy in Medicaid program design (Commonwealth Fund). It is possible that 1115 expansion states may have increased insurance coverage that may have impacted health outcomes in non-expansion states.

Overall, these results indicate that Medicaid expansion was not associated with uptake in vaccination coverage among low income children, even when analysis was restricted to the most low-income children. These results are encouraging in their support for the benefits of other safety-net programs for children, including CHIP and the Vaccines for Children program. This indicates that spillover effects from Medicaid expansion for MMR vaccination and 7-series vaccination coverage are negligible. However, persistent vaccination coverage gaps between low income and higher income children, though shrinking, may indicate the further intervention beyond coverage expansions are necessary bridge the gap between these two groups of children.

Strengths

This study has several strengths. We are not aware of any other study that has looked at the impact of coverage expansions on vaccination rates, and we provide useful insight and quantification of the relationship between coverage expansions over an eight-year period. Few studies have evaluated the impact of Medicaid itself within the context of childhood vaccinations, despite studies that have quantified the relationship between insurance status and vaccination coverage. The use of a differences-in-differences quasi experimental model allows for an estimation of casual effect, giving this analysis robustness in its assessment of the casual impact of Medicaid expansion on these specific outcome measures. Our outcome measures are similarly look at two different aspects of vaccination initiation and completion of vaccination series, since this analysis looked at 7 series completion, which is a marker of up to date vaccination status, as well as at least one dose of MMR containing vaccine. The use of multiple years of data as well as the large sample size and individual level analysis provided enough power to detect effect size among, even among subgroups. Results were consistent across multiple study period and sample definitions, as well as to adjustment for a linear time trend, adding robustness to the findings.

Limitations

The study also has several limitations. Firstly, use of MMR and 7 series vaccination completion are not an exhaustive measure of vaccination coverage, making it difficult to draw conclusions about coverage expansion and vaccination coverage broadly, or for vaccinations that may be repeated more frequently, such as the flu. Information on insurance status and date of vaccination was not available in the NIS-Child, making it impossible to look at changing insurance coverage levels among the sample, as well as to adjust for lag time in vaccination uptake. Due to the time frame of the data, it was not possible to analyze the effect of rising levels of uninsured children related to expansion status, but it is possible there may be a downstream effect of this on vaccination rates. Finally, the difference-in-differences approach may be subject to bias if other time-varying unobserved factors may have differentially affected expansion, though trends in observed confounders were similar among both groups. However, it is possible that unobserved factors and policies may have played a role into this relationship, such as attitudes towards vaccination, physician-parent relationship, other Medicaid related state policies (such as eligibility checks, outreach funding, etc), and state unemployment rates may be related to expansion status and vaccination coverage rates. However, our analysis adjusts for factors common in quantifying the impact of Medicaid expansion, and adjusted for factors known to relate to both the exposure and the outcome to eliminate the potential for confounding. Other factors that are associated with vaccine decisions, such as information given by health care providers, personal network characteristics, parent-provider communication, and provider trust were unobserved in this dataset, and may have differed between expansion and non-expansion states (Sarker, 2019). However, the random digit dialing nature of the sample makes it unlikely individual level vaccination attitudes would be significantly different between expansion and non-expansion states, and the use of multiple states makes it unlikely individual state policies may have a significant impact on the results.

Future directions

This study provides useful insight into the potential benefits of public vaccination programs, as well as for public health practice and policy. This highlights the continuing importance of funding for public vaccination programs. However, coverage expansions may not be sufficient to close the vaccination disparity among low income children. While public programs exist to provide vaccination services to uninsured children and increase access, to close the gap in vaccination coverage among low income children, it may be more beneficial to focus on other interventions that shape vaccine uptake. This includes combination vaccines, patient counselling, public education and reminder strategies, financial incentives, and use of EMR reminders (Ventola, 2016). More work on the impacts of these strategies in conjunction with insurance coverage may help develop a clear policy strategy to improve vaccination rates among low income children. Future work might also look at other vaccinations, especially flu vaccination, as access to preventive services among adults has been shown to be impacted by coverage expansions. Other studies might aim to look at the impact of the rise of uninsured children on vaccination coverage, to see if Medicaid related policies but not expansion itself may be associated with vaccination rates. Despite the limitations of the study, this study provides support for the impact of existing safety net programs, as spillover effects did not impact vaccination rates among low income children in the four years since full implementation of Medicaid expansion. Further work is needed to understand the relationship between health insurance policies, insurance status, and vaccination rates to identify best practices and ways to reduce future outbreaks of childhood diseases and ensure equity across socioeconomic status.

Table 1. *Characteristics of low-income individuals, according to Medicaid expansion status and calendar time (excluding 2014). Standard errors of mean frequency indicated in parentheses.*

	2010-2013 (N=16,823)*		2015-2018 (N=19,768)*	
Characteristic	Expansion (N = 9,056)*	Non-expansion (N =7,767)*	Expansion (N =10,439)*	Non-expansion (N = 9,329)*
Age group				
19-23 months	29.50 (0.93)	30.16 (0.75)	29.82 (1.10)	30.00 (0.77)
24-29 months	33.81 (0.94)	33.81 (0.78)	33.72 (1.17)	34.08 (0.81)
30-35 months	37.34 (0.96)	36.02 (0.77)	36.46 (1.14)	35.95 (0.79)
Sex				
Male	25.81 (0.55)	24.13 (0.43)	25.87 (0.66)	25.25 (0.47)
Female	26.38 (0.56)	23.68 (0.43)	25.08 (0.65)	23.01 (0.47)
Race/ethnicity				
Hispanic	46.31 (0.89)	36.12 (0.75)	43.90 (1.12)	34.40 (0.75)
Non-Hispanic white	29.61 (0.73)	30.82 (0.70)	29.46 (0.83)	30.64 (0.74)
Non-Hispanic black	13.67 (0.56)	24.09 (0.70)	14.32 (0.68)	23.97 (0.78)
Other/Multiple races	10.41 (0.52)	8.97 (0.46)	12.32 (0.73)	10.99 (0.47)
Educational status of mother (years)				
<12	35.72 (0.99)	33.27 (0.77)	30.02 (1.18)	26.93 (0.76)
12	38.23 (0.90)	38.90 (0.81)	39.07 (1.18)	39.87 (0.83)
>12, not college graduate	20.16 (0.67)	22.40 (0.62)	24.10 (0.93)	25.20 (0.70)
College graduate	5.90 (0.36)	5.43 (0.30)	6.80 (0.40)	8.00 (0.40)
# of children in household				
1	20.12 (0.81)	20.54 (0.66)	20.03 (0.87)	22.96 (0.72)
2 or 3	57.54 (0.99)	56.63 (0.80)	59.06 (1.18)	57.22 (0.83)
4+	22.33 (0.83)	22.83 (0.67)	20.91 (1.03)	19.82 (0.65)
Marital status of parents				
Married	43.71 (0.99)	39.79 (0.77)	39.30 (1.18)	35.32 (0.76)
Unmarried†	56.28 (0.99)	60.21 (0.77)	60.70 (1.18)	64.68 (0.76)

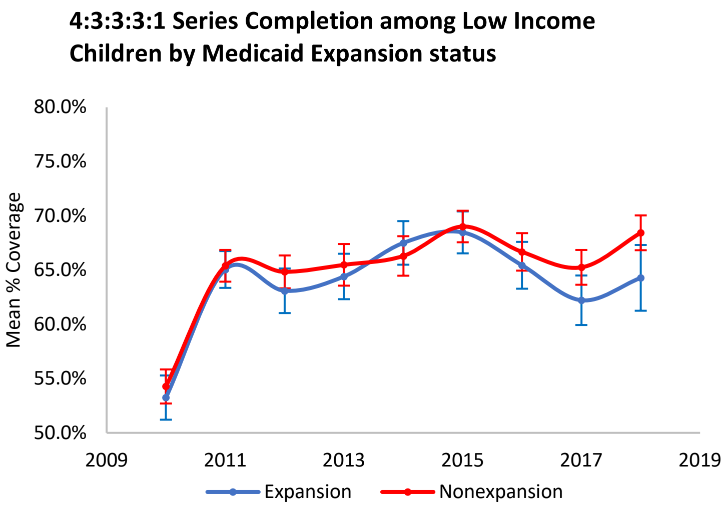
* indicates unweighted frequency

†including never married, widowed, divorced, separated, deceased, living with partner

All statistics and standard errors were adjusted for survey weights.

Figure 1 and Figure 2. Trends in vaccination completion among low income children according to Medicaid expansion status.

Shown are weighted mean percent of children with vaccination coverage, with standard errors calculated for states that implemented Medicaid expansion by the end of 2015 according to survey year, from 2010 to 2018.



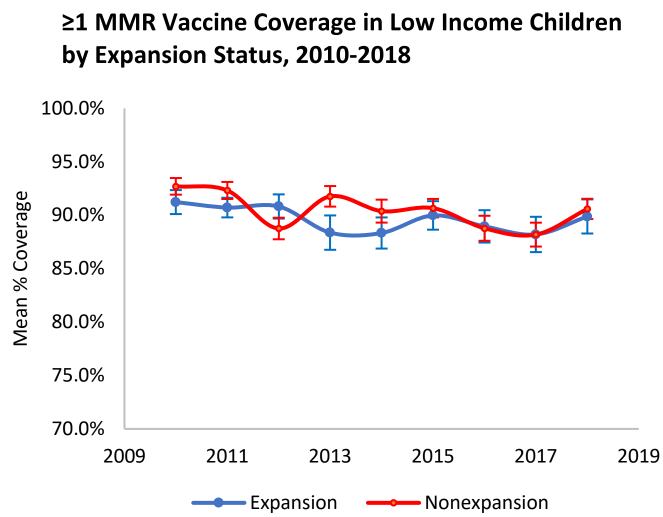


Table 2. Changes in MMR vaccination coverage and 7-series vaccination completion associated with Medicaid expansion status. Shown are mean percentage of vaccination completion and mean percent difference. Standard errors of estimates are indicated in parentheses.

Outcome Measure	Expansion: Pre-expansion (2010-2013)	Expansion: Post-expansion (2015-2018)	Non-expansion: Pre-expansion (2010-2013)	Non-expansion: Post-expansion (2015-2018)	Difference in differences estimate†	Adjusted p-value
≥1 MMR vaccine	90.30 (0.60)	89.27 (0.75)	91.36 (0.44)	89.57 (0.51)	0.82 (0.12)	0.48
7 series vaccination	61.54 (0.97)	65.23 (1.16)	62.54 (0.79)	67.37 (0.79)	-0.84 (0.12)	0.65

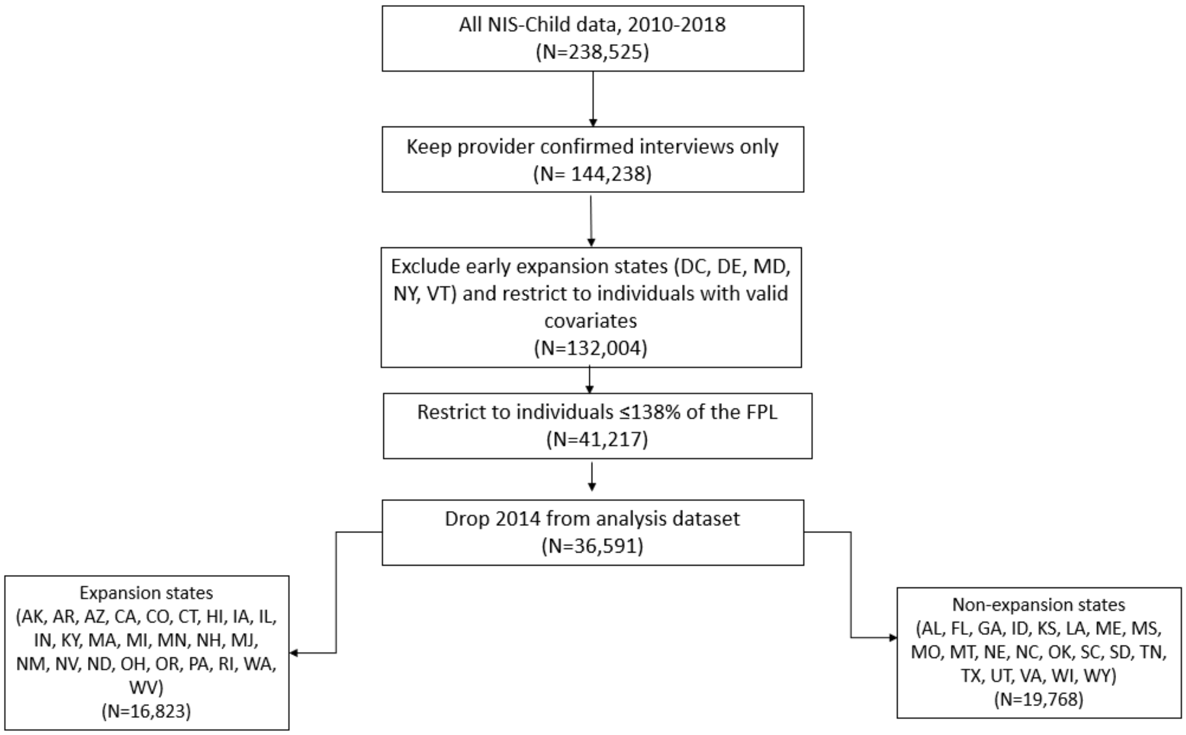
†The difference in difference estimators are adjusted for age group, census region, number of children in household, expansion, post, sex or child, race/ethnicity, education status of mother, and marital status of parents and is expressed in mean difference in percentage

Table 3. Changes in MMR vaccination coverage and 7-series completion associated with Medicaid expansion status with differing sample definitions. Shown are mean percentage of vaccination completion and mean percent difference. Standard errors of estimates are indicated in parentheses.

	100% FPL individuals		*With 2014 as the start of the "post" period*		*Controlling for linear time trend*	
Outcome	Adjusted D-I-D (SE)	p-value	Adjusted D-I-D (SE)	p-value	Adjusted D-I-D (SE)	p-value
≥1 MMR vaccine	-0.25 (2.0)	0.90	0.8 (1.2)	0.51	0.8 (1.2)	0.49
7 series vaccination	0.54 (1.0)	0.68	-1.4 (1.9)	0.47	-0.8 (1.9)	0.66

Appendix

Figure S1: *Flow Diagram of Sample Definition*



Details on Regression Specifications

$$Y_{it} = B0 \; + \; B1 \, X_{it} + B2 \; expansion \; + B3 \; Post + B4 \; expansion \times post + \epsilon_{it}$$

(1) Y_{it} is an outcome measure (e.g. mean MMR coverage),
(2) X_{it} is a set of indicators for individual level covariates, including age group of child, number of children in household, education status of mother,
(3) $Expansion$ is an indicator that an individual is in an expansion or non-expansion state
(4) $Post$ is an indicator for each time period that is set to 1 if that period is after Medicaid expansion by 2015
(5) $Post \times Expansion$ is a full interaction

Table S1: *Full Regression Model Results for MMR and 7-series completion.*

Shown are coefficient estimates (representing mean percent change) from the multivariate linear regression model. Full model includes the difference-in-difference term specified in Table 2.

	MMR		*7-series completion*	
Characteristic	Estimate (%)	p-value	Estimate (%)	p-value
Census region				
Northeast	2.82	0.01	3.10	0.08
Midwest	1.37	0.15	1.12	0.43
South	2.81	0.002	2.34	0.09
West	-	-	-	-
Age group				
19-23 months	-	-	-	-
24-29 months	3.65	<0.001	5.00	<0.001
30-35 months	4.09	<0.001	7.24	<0.001
Expansion status				
Non-expansion	-	-	-	-
Expansion	0.09	0.90	-0.62	0.90
Time period				
Pre-expansion	-	-	-	-
Post-expansion	-1.92	0.005	4.37	<0.0001
Sex				
Male	0.24	0.68	1.42	0.13
Female	-	-	-	-
Race/ethnicity				
Hispanic	4.66	<0.0001	8.37	<0.0001
Non-Hispanic white	-	-	-	-
Non-Hispanic black	1.87	0.02	1.08	0.39
Other/Multiple races	2.37	0.01	1.75	0.24
Educational status of mother (years)				
<12	-	-	-	-
12	2.63	0.0004	3.87	0.002
>12, not college graduate	1.80	0.035	4.29	0.0008
College graduate	1.26	0.01	4.86	0.004
# of children in household				
1	-	-	-	-
2 or 3	-1.40	0.05	-4.51	0.0001
4+	-4.04	<0.0001	-1.16	<0.0001
Marital status of parents				
Married	1.37	0.03	1.07	0.29
Unmarried†	-	-	-	-

†including never married, widowed, divorced, separated, deceased, living with partner

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